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PLOWSHARE PROGRAM

PROJECT GNOME

PRELIMINARY REPORT — PROJECT 1.8

MICROBAROGRAPH MEASUREMENTS

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MICROBAROGRAPH MEASUREMENTS

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January 1962

ABSTRACT

Air-pressure signals from the underground Gnome detonation were investigated with on-site pressure gages and off-site microbarographs. Unusual weather and an insufficient number of measurement stations resulted in no off-site recordings. Useful data were obtained on site to further aid in source descriptions from underground blasts.

CONTENTS

INTRODUCTION

Objectives

The purpose of the microbarograph measurements project was to establish whether air-pressure signals from deep underground explosions can be positively recorded at large distances. It was also desired to investigate burial attenuation factors and distance decay laws.

Background

Pressure waves propagated through the atmosphere from Nevada Test Site (NTS) underground nuclear tests have been recorded at 135 miles range (Reference 1). These waves are carried in the sound duct caused by high temperatures and winds in the ozonosphere near 150,000-foot altitudes. Recorded amplitudes were generally at least 10 percent as large as would have been expected from the same yields burst on the surface. Subsequent data collected from Plowshare underground high-explosive tests have also shown that there is less attenuation at great distance from buried shots than appears at close range, and that attenuation factors appear to decrease with increased yields at and beyond a few miles range (References 2,3).

According to preliminary data from Project Banshee (Reference 4), air blast appears to decay with distance, i.e., $\Delta p \sim R^{-1.2}$, to long distances such as 2 million feet from 1-kt free air bursts. Combining these data shows that Gnome, 5 kt at 1200-foot depth, would give a 26-microbar overpressure signal at 135 miles, provided, of course, that atmospheric refraction returns sound rays at this range.

PROCEDURE

Operation

It was originally planned to field eight microbarographs for Gnome, but with resumption of underground tests in Nevada, equipment and personnel were limited and the number was cut to two. Each microbarograph was placed on a line east of Gnome to take advantage of the winter westerly winds in the ozonosphere. Big Spring, Texas, at 132 miles, was chosen, based on Nevada experience, as being at optimum refracted first return distance; Abilene, Texas, was considered a convenient spot to essentially double attempted detection distance.

On-site pressure gages were spaced at 40, 1000, and 2500 feet from ground zero to measure source strength as seen at ground level. A 2400-pound high-explosive (HE) charge was mounted on a 15-foot tower (to enhance air-blast yield) located 1 1/2 miles north-northwest of ground zero. This shot, to be fired at plus 5 minutes, was to serve as a calibration point for comparison of underground and surface blasts. One pressure gage at 300 feet from the HE was positioned to verify its yield. Scheduling the HE at plus 5 minutes was to allow for signal discrimination and preservation of HE in case of last minute delays of Gnome.

Instrumentation

Microbarographs used for this project were much the same as those used for years in recording nuclear tests. Differential pressure-wave sensors were twisted Bourdon tubes which turned an armature with respect to an E-core, varying

reluctance to modulate a carrier wave transmitted by coaxial cable to appropriate signal amplifiers for recording. Sensors were produced by Wiancko Corporation, Pasadena, California, as specified and evaluated by Sandia Corporation (Reference 5). Amplifier systems in current use were designed at Sandia and built by Electronic Engineering Company, Santa Ana, California. Brush Electronics Company pen-type trace recorders were used at 2.5 cm/sec paper speed. One-second time marks were produced by an event marking pen. Reference time marks were made manually; previously synchronized watches were used for determination of the latter marks.

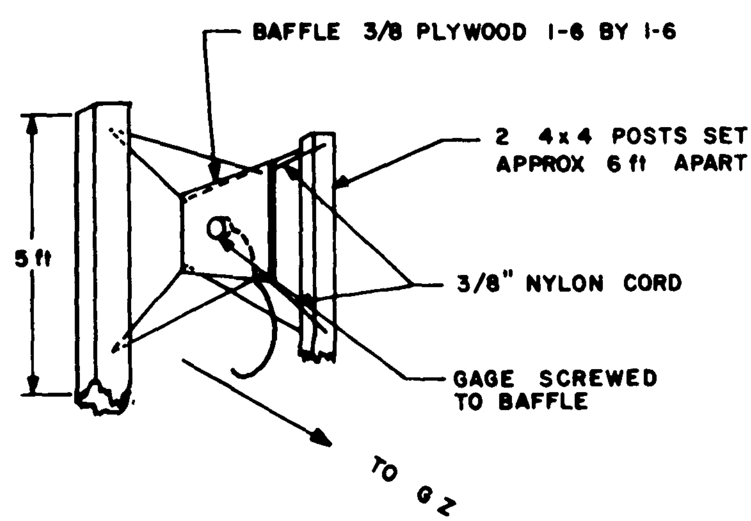
Instrument and recorder response time for pressure signals was such that 95 percent amplitude of a square wave pressure pulse would be recorded in about 15 milliseconds. Thus, there is very little damping for signals of frequency lower than 10 cps.

Sensitivity ranges for Sandia microbarographs are such that signal amplitudes from 1 microbar (1 dyne/cm^2) to 48 millibars may be satisfactorily recorded, provided wind noise at low levels or blast damage at high levels is not excessive. Recent calibration tests have shown that about 85 percent of previous recordings were accurate to $\pm$ 20 percent. A new air-pressure pump calibration system has been constructed to augment the old water-manometer calibration technique, and future measurements should be more accurate and reliable over the entire operating range.

The on-site pressure gages, also of Wiancko manufacture, Type P1404 (Reference 6), allowed measurement of higher pressures. The set ranges used are indicated below. Gage locations

Gage location	Set range (psi)
HE - 300	3.0
GN - 40	0.5
GN - 1000	0.1
GN - 2500	0.1

are shown in Figure 1. Recording from all four gages was done on a magnetic tape recorder located near the 2500-foot station in Sandia trailer "M." Method of placement of GN-designated gages was as shown in the sketch below. This plan was intended to reduce expected direct ground accelerations. For side-on measurements, it was necessary that the baffle and gage be oriented perpendicular to the post line because of incorrect post installation. Such installation may have been superfluous, since acceleration tests have shown response perpendicular to the transverse axis to be between 0.001 and 0.05 percent of range per g acceleration. However, the additional precaution was thought to be desirable.



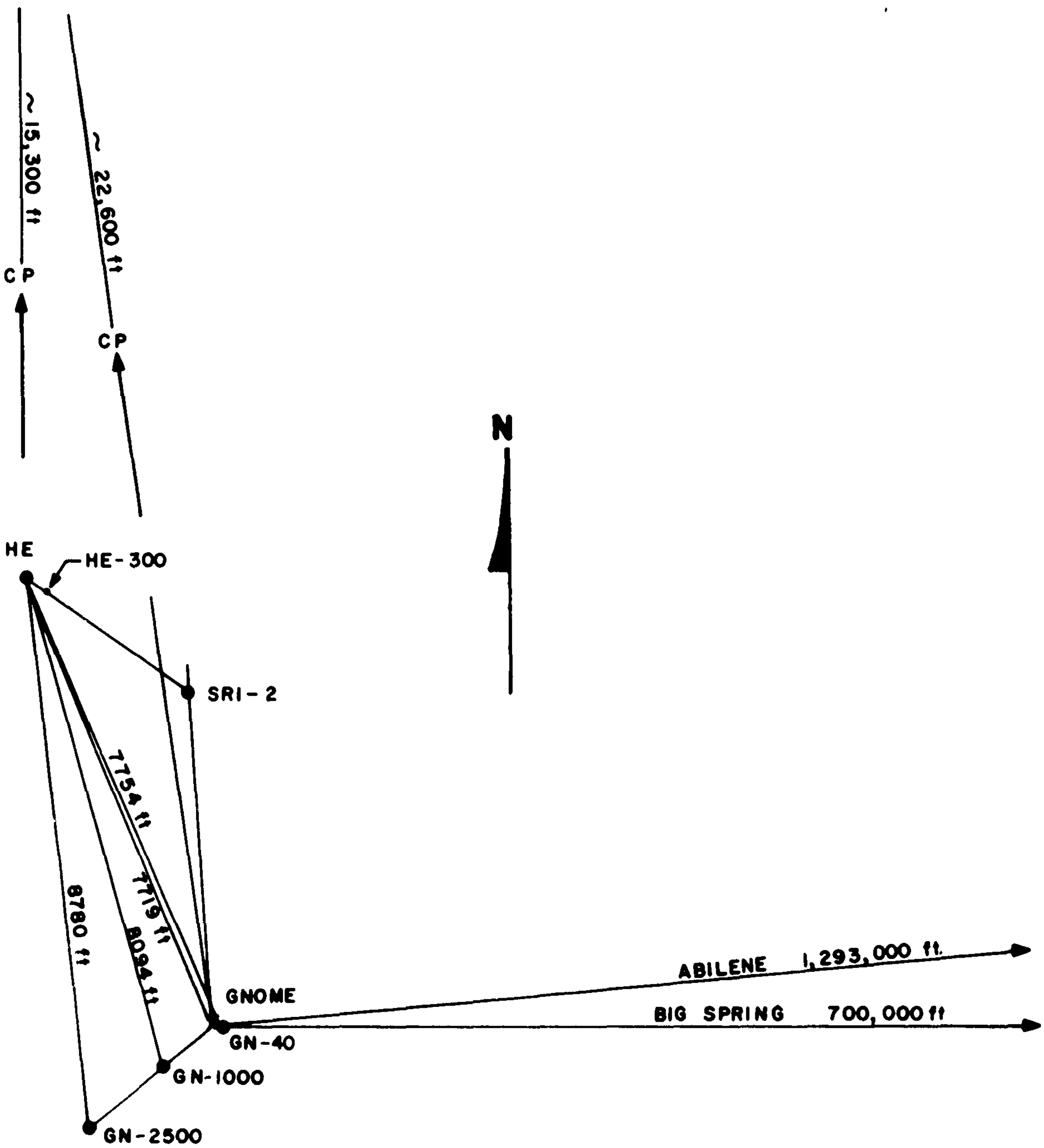


Figure 1. Gnome pressure-gage array.

In addition to on-site Wiancko gages, four self-recording BRL (Ballistic Research Laboratories) gages were located at 114, 300, 330, and 3680 feet from the HE shot at set ranges of 10, 3, and 0.1 psi. These were operated with the assistance of BRL personnel who also reduced the data. The intent here was to test portable-type gages with a view toward use of similar instrumentation on future shots.

RESULTS AND DISCUSSION

Gnome was fired at exactly noon (MST), December 10, 1961, after four hours of delay caused by unfavorably directed low-level winds. The HE shot fired prematurely, apparently caused by early triggering of the fire control relays located about one mile north of Gnome. All recorders operated as planned, both off and on site.

Weather

Atmospheric acoustic propagation is a strong function of temperature and wind structure. High-speed winds from west-southwest had been prevalent in the upper troposphere for several days over the area, apparently reaching a maximum on shot day (230 degrees at 190 knots at 38,000 feet). Meanwhile a cold polar outbreak had pushed southward over the central plains regions, causing cold temperatures and high surface winds over most of Texas and eastern New Mexico. Table 1 shows a composite wind and temperature sounding constructed from the following sources:

TABLE 1--ATMOSPHERIC SOUNDING

Altitude (kft)	Temperature (°C)	Wind Direction (degrees)	Wind Speed (knots)	Altitude (kft)	Temperature (°C)	Wind Direction (degrees)	Wind Speed (knots)
3.2	7.4	140	6	40	-60.5	240	130
3.5	6.5	140	8	45	-67.8	240	132
4	5.2	160	14	50	-64.3	240	112
5	3.8	180	17	60	-62.0	230	74
6	4.3	200	22	70	-59.0	240	27
7	3.2	220	26	80	-57.5	240	42
8	2.1	220	25	90	-51.0	260	75
9	0.4	230	24	100	-46	265	100
10	-1.3	240	26	110	-41	269	118
12	-4.8	240	33	120	-33	266	103
14	-8.3	240	41	130	-24	280	91
16	-11.8	240	55	140	-15	262	133
18	-15.8	240	53	150	-9	263	155
20	-20.4	240	52	160	-2	262	160
23	-27.8	240	64	170	-2	264	190
25	-32.2	240	70	180	-5	275	190
30	-40.0	240	112	190	-11	281	158
35	-50.0	230	175	200	-18	281	116
38	-57.0	230	190				

1. Shot-time RAOB to 15 kft MSL altitude
2. 1030 MST on-site PIBAL to 6 kft MSL altitude
3. 0500 Midland, Texas, RAWIN to 93 kft MSL altitude
4. 1700 Midland, Texas, RAWIN to 37 kft MSL altitude
5. White Sands rocket wind
   (chaff) 1100 MST December 11 to 130 kft MSL altitude
6. White Sands rocket wind
   (chute) 1015 MST December 12 to 200 kft MSL altitude
7. ARDC Standard Atmosphere temperatures for 100 to
   200 kft altitude

This sounding is preliminary only in that on-site shot time winds are not yet available and their addition will be the only change (item 2 above). Gusty surface winds of 15 to 25 knots at Big Spring and Abilene created background noise on the microbarographs, causing signal identification to be difficult.

Microbarograph

Careful inspection of the microbarograph records yielded no positively identifiable shot signal from either HE or underground shot. A ray-trace calculation, in which the above sounding structure was used, was made which gives distance, arrival time, and expected pressure (for specified shot yield) for various selected elevation angles of sound rays from burst point. Figure 2 shows, as a function of elevation angle, a plot of calculated distance out to first ground strike and mean travel speed. This plot is used as a guide for closer inspection of the records to aid signal identification. The integers on the bottom indicate where multiple skips relative to the two stations would originate. Signal discriminations between HE and Gnome should not have been too serious a

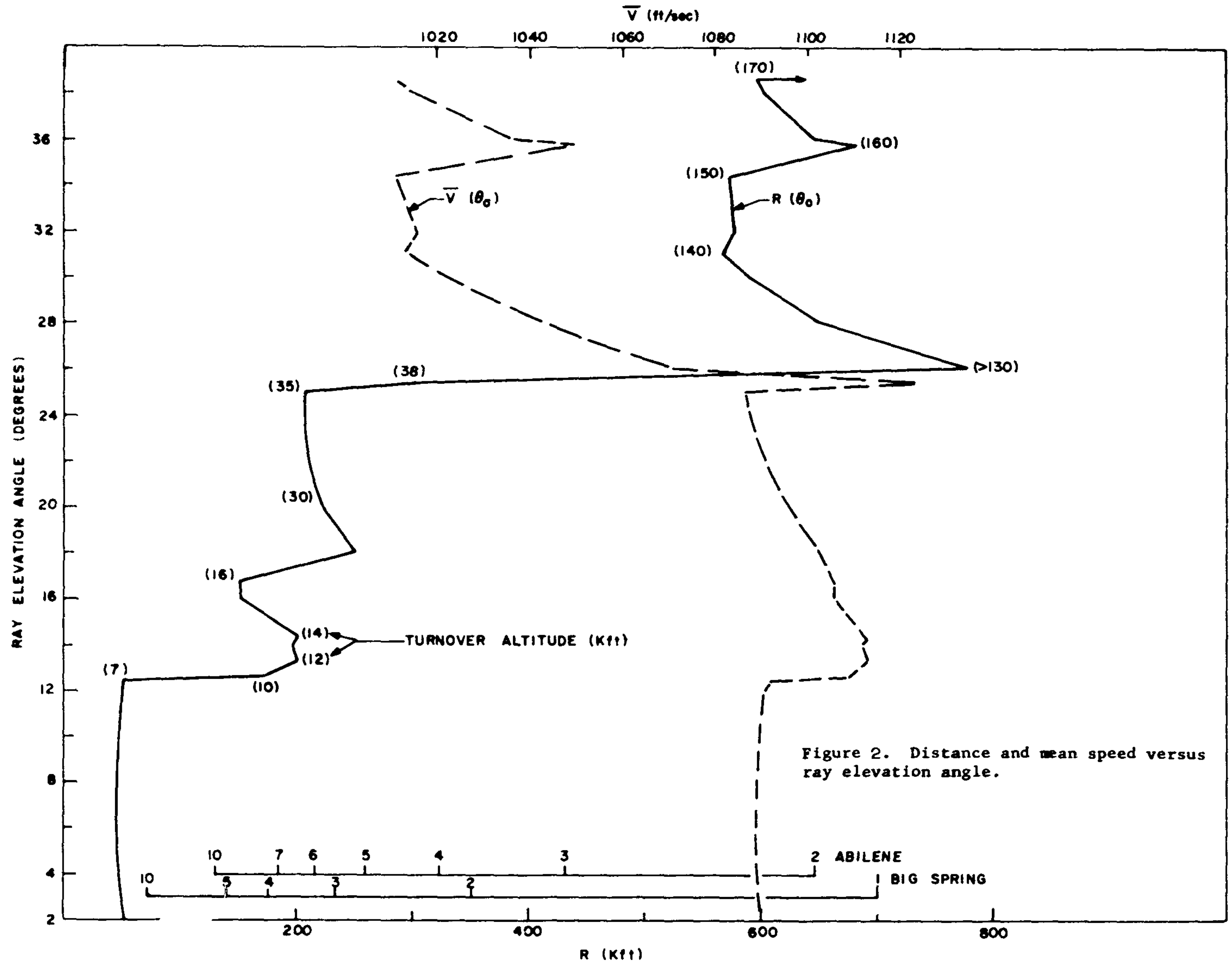


Figure 2. Distance and mean speed versus ray elevation angle.

problem since, as will be shown later, the HE, located almost 3000 feet farther west, apparently fired 0.88 second after the Gnome detonation. However, the point is academic, since sorting either signal out of the noise appears to be impossible. As can be seen from Figure 2, the major ozonosphere return lies between 109 and 129 miles, with highest concentration at 109 miles. This is obviously short of the expected 125- to 140-mile range observed under more normal conditions in Nevada. It would appear that, had the microbarograph locations been about 20 miles farther upwind, identifiable signals probably would have been present.

On-Site Gages

The on-site gage array is shown in Figure 1. Distances shown are in feet. While a considerable amount of 60-cps noise was introduced at the recorder on all channels, and calibration drift occurred on the two 0.1-psi gages, pressure information is still discernible on all gages. Figure 3 contains free-hand traces (averaged by eye through the 60-cycle hum) of the first 2 seconds of each gage record. The general character of the 40-foot record bears a remarkable resemblance to accelerometer data taken not far away by Sandia (Reference 7). The three peaks were 0.39, 0.72, and 0.22 psi at arrival times of 0.18, 1.18, and 1.70 seconds, respectively. It is felt that pressure records were faithfully represented since gage acceleration response was very small (see section on instrumentation).

All four gages recorded the HE shock wave from which an estimate of HE firing time can be made. Of course, the best estimate comes from the closest gage, but confirmation from

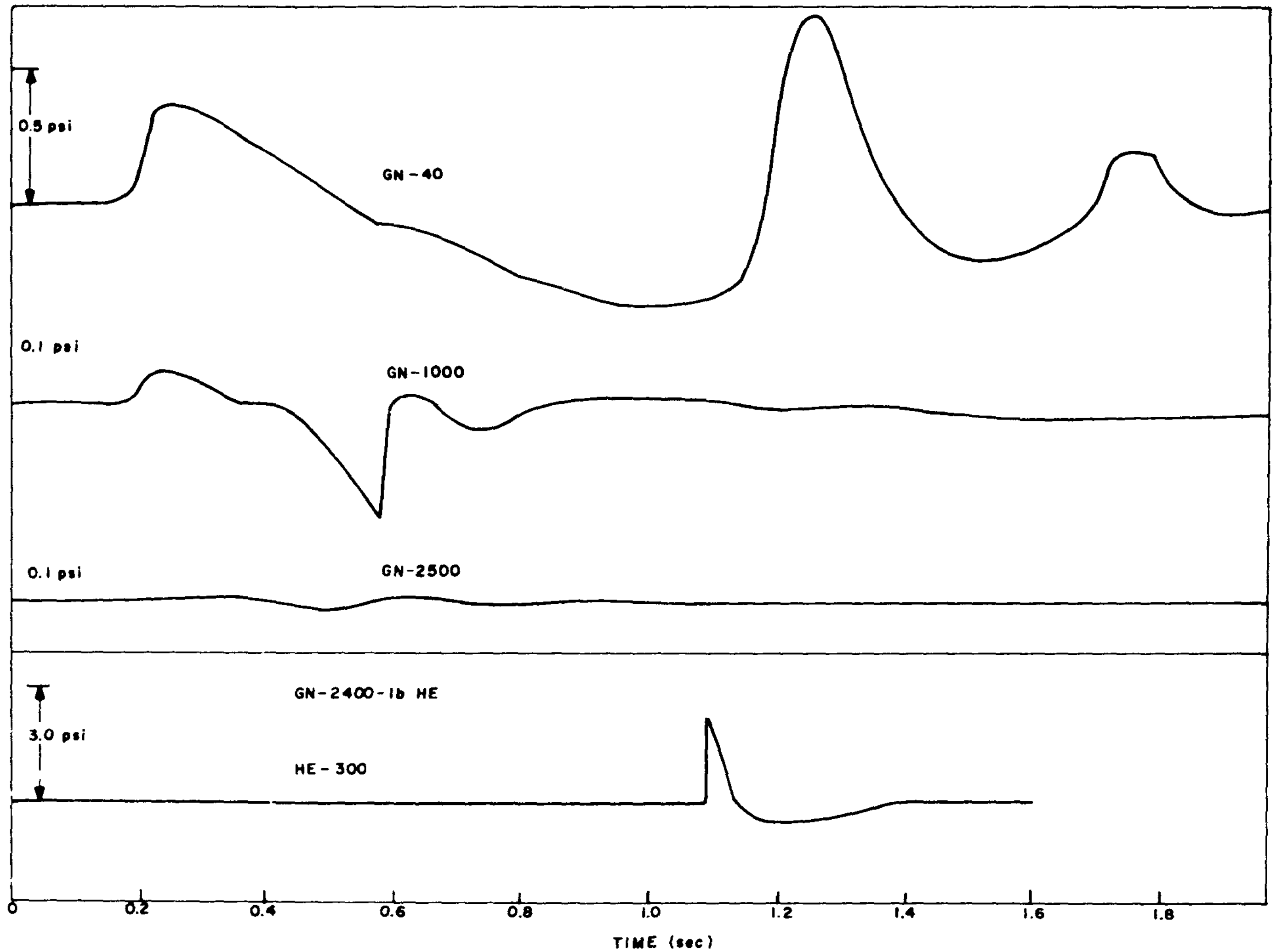


Figure 3. On-site pressure records.

the other three is desirable. Theoretical travel times were scaled down from IBM Problem M Curves (Reference 8) and best estimates of on-site weather. Two cases were calculated using 7.4 degrees Centigrade temperature together with winds of 140 degrees at 6 knots and 140 degrees at 13 knots. Table 2 lists each gage, range, two calculated travel times (T_{C1}, T_{C2}), observed arrival time (T_0), and two differences between observed and calculated times (ΔT_1, ΔT_2) all in seconds.

TABLE 2--TRAVEL TIMES

Gage	Range (ft)	T_{C1}	T_{C2}	T_0	ΔT_1	ΔT_2
HE - 300	300	0.21	0.21	1.09	0.88	0.88
GN - 40	7754	7.00	7.09	7.95	0.95	0.86
GN - 1000	8094	7.31	7.40	8.28	0.97	0.88
GN - 2500	8780	7.94	8.04	8.90	0.96	0.86

The sensitivity of travel time to distant gages under differing wind situations is evident. Upon receipt of shot-time winds a ray tracing calculation will be made for verification. However, selection of 0.88 second for HE firing time after Gnome zero seems obvious.

CONCLUSIONS

The primary objective of Project 1.8, i.e., comparison of underground to above-ground explosive acoustic air-pressure signals at large distance, was not accomplished. Reasons include atypical atmospheric sound propagation conditions at shot time and an insufficient number of microbarograph stations to allow for this. More stations had been planned originally, but a priority commitment for Operation Nougat at Nevada Test Site caused a reduction from eight to only two stations.

The on-site gages gave results which will be useful in describing air-pressure source function from underground blasts as seen at ground level.

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